The Location of Peak Upper Trapezius Muscle Activity During Submaximal Contractions is not Associated With the Location of Myofascial Trigger Points: New Insights Revealed by High-density Surface EMG

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DOI:
10.1097/AJP.0000000000000373
10.1097/AJP.0000000000000373

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The authors certify that they have NO affiliations with or involvement in any organization or entity with any financial interest or non-financial interest in the subject matter or materials discussed in this manuscript. For this study no funding sources were provided

ABSTRACT

AIM: To apply topographical mapping of the electromyography (EMG) amplitude recorded from the upper trapezius muscle to evaluate the distribution of activity and the location of peak activity during a shoulder elevation task in subjects with and without myofascial pain and trigger points (MTrP) and compare this location with the site of the MTrP.

METHODS: Thirteen subjects with myofascial pain and MTrP in the upper trapezius muscle and 12 asymptomatic subjects participated. High-density surface EMG was recorded from the upper trapezius muscle using a matrix of 64 surface electrodes aligned with an anatomical landmark system (ALS). Each subject performed a shoulder elevation task consisting of a series of 30 s ramped contractions to 15% or 60% of their maximal voluntary contraction (MVC) force. Topographical maps of the EMG average rectified value were computed and the peak EMG amplitude during the ramped contractions was identified and its location determined with respect to the ALS. The location of the MTrP was also determined relative to the ALS and Spearman's correlation coefficients were used to examine the relationship between MTrP and peak EMG amplitude location.

RESULTS: The location of the peak EMG amplitude was significantly ($p<0.05$) different between groups (subjects with pain/MTrP: -0.32 ± 1.2 cm at 15% MVC and -0.35 ± 0.9 cm at 60% MVC relative to the ALS; asymptomatic subjects: 1.0 ± 1.3 cm at 15% MVC and 1.3 ± 1.1 cm relative to the ALS). However, no correlation was observed between the position of the MTrP and peak EMG amplitude during the ramped contractions at either force level (15%: $r_s = .039$, $p = .9$; 60%: $r_s = -.087$, $p = .778$).

CONCLUSION: People with myofascial pain and MTrP displayed a caudal shift of the distribution of upper trapezius muscle activity compared to asymptomatic individuals during a submaximal shoulder elevation task. However, for the first time, we show that the location of peak muscle activity is not associated with the location of MTrP.

INTRODUCTION

Myofascial trigger points (MTrP) are considered to be a common cause of primary or secondary muscle pain. Local or referred pain elicited by active MTrP can contribute to pain symptoms in people with several different musculoskeletal conditions [1-5]. Although several factors, such as muscle trauma, repetitive low-intensity muscle overload, intense muscle contraction, or psychological stress, have been suggested to play an important role in the activation of MTrP, the etiology remains speculative [6-8].

Hubbard and Berkoff conducted the first needle electromyography (EMG) investigation of MTrP in the upper trapezius muscle and described two abnormal patterns; a low amplitude persistent activity of 50 μV and intermittent higher amplitude spike-like activity of 100-700 μV [9]. Such spontaneous and persistent background EMG activity of the MTrP were supported by further investigations [10-13]. However, the origin of such activity has been debated. Possible explanations include dysfunctional endplates located nearby the MTrP [14-16].

More recently, Chung et al measured EMG from seven subjects with MTrP in the trapezius muscle. Needle EMG was recorded from the tender area and control sites at various depths for a prolonged time. All subjects exhibited a reliable resting EMG signal identified at subject-specific depths which were not associated with general muscle activation [17]. The atypical electrical activity was interpreted as motor unit action potentials and their prevalence closely correlated with the pressure pain threshold of the MTrP [13]. Furthermore, a study evaluating people with latent MTrP in the upper trapezius muscle documented early myoelectric manifestations of fatigue of the upper trapezius during sustained isometric contractions, and notably the muscle fibers close to the latent MTrP exhibited an anticipated and significant increase in surface EMG amplitude [18]. An increase of the intramuscular EMG amplitude of the trapezius muscle has also been observed in subjects with latent MTrP during synergistic muscle activation [19].

Based on these observations, it may be expected that the distribution of activity of the upper trapezius muscle would be different in people with MTrP and that the location of the peak activity may even be located at the site of the MTrP. However, until now, methodological limitations have prevented this investigation.

High-density, two-dimensional surface EMG provides a measure of the electric potential distribution over a large surface area during muscle contraction [20-22]. Unlike classic bipolar EMG applications, this method provides a topographical representation of EMG amplitude, and can identify the intensity of activity within regions of a muscle and the location of the peak EMG amplitude across a large region of the muscle. High-density EMG studies have confirmed that either acute experimental muscle pain [23] or chronic clinical pain [24, 25] may alter the distribution of muscle activity and may cause a shift of the peak muscle activity. Considering these findings, it may be speculated that a long-lasting nociceptive irritant, such as a MTrP, could induce a spatial reorganization of muscle activity however this has never been evaluated.

In this study we extracted topographical maps of the upper trapezius surface EMG amplitude to evaluate the distribution of muscle activity and the location of peak activity during a submaximal shoulder elevation task in subjects with and without myofascial pain and MTrP within the upper trapezius muscle. For the first time, we examined the relationship between the location of the MTrP spot tenderness and the location of the peak EMG amplitude. We hypothesized that the distribution of upper trapezius muscle activity and therefore the location of the peak activity during a shoulder elevation task would be different in people with MTrP compared to those without and that the location of the peak may correspond to the location of the spot tenderness.

METHODS

Experimental sessions were conducted between May and June 2012 in the Laboratory of Movement Analysis at Vita-Salute San Raffaele University, Milan, Italy. The study was approved by the Internal Ethics Committee and conducted in accordance with the Declaration of Helsinki. All participants signed an informed consent form before enrolling in the study.

Participants

A convenience sample of twelve asymptomatic subjects (seven men; age, mean±SD: 21.8 ± 1.4 years) and 13 (six men; age: 22.8 ± 3.5 years) individuals with myofascial pain and the presences of at least one MTrP in right upper trapezius muscle participated in the study following advertisement at the Vita-Salute San Raffaele University. The inclusion criteria for asymptomatic subjects were no sign or symptom of musculoskeletal pain in the cervical region, thoracic region and upper limb, and the absence of a clinically relevant MTrP in the right upper trapezius muscle. The inclusion criteria for the symptomatic group was at least one clinically relevant MTrP [26] in the right upper trapezius muscle and reported pain over the upper trapezius muscle in the last 2 weeks. All subjects in both groups were right hand dominant. The exclusion criteria for both groups were: history of neurological or rheumatic disorders, cervical radiculopathy or radicular pain in the previous 6 months, whiplash injury in the previous 6 months, the presence of mental or emotional disorders, the presence of scars or moles in the area of the upper trapezius muscle, pregnancy, and a body mass index of 30 or higher.

The clinical examination to detect the presence of MTrP was performed by an expert physiotherapist with more than 10 years of experience in the diagnosis and management of myofascial pain syndromes. Diagnostic criteria for a clinically relevant MTrP were: the presence of a palpable taut band, the presence of spot tenderness within the taut band, and the elicitation by manual palpation of either one or a combination between pain recognition and referred pain [26]. Pain recognition was defined as the reproduction of a familiar pain by manual compression of the MTrP spot tenderness. If more than one MTrP was detected, the MTrP which elicited a familiar pain was considered. If the subject was not able to distinguish between two MTrPs and they reported familiar pain at both sites, the examiner asked the subject to identify the most painful MTrP on palpation.

Procedure

The subject was seated with their back supported, knees and hips flexed to 90°and their arms by their side in a relaxed position. An operator marked a standardized anatomical landmark system (ALS) over the right shoulder region of all subjects while they were seated [27]. The ALS consisted of a line between the spinous process of the seventh cervical vertebrae and the acromial angle (X-axis), and a second line perpendicular to the first passing through its midpoint (Y-axis). The distance between the spinous process of the seventh cervical vertebrae and the acromial angle was measured using a measuring tape.

A palpation examination was performed on all subjects. For the subjects with myofascial pain, the examination was performed to confirm the presence of a clinically relevant MTrP, while for asymptomatic subjects it was performed to exclude the presence of any MTrP and specifically any spot tenderness within any taut band of the upper trapezius muscle. For the subjects with myofascial pain and MTrP, the examiner marked the location of the MTrP on the skin using a custom designed stamp (1 cm2 circle with a dot in the centre). The dot in the centre was overlapped with the spot tenderness, and its distance from the X- and Y-axes of the ALS was measured with a measuring tape. Pain pressure threshold (PTT) over the spot tenderness was recorded using an algometer (Wagner Instruments, Greenwich, CT, USA). The contact area of the algometer tip was 1 cm^2 and the application rate was approximately 1 kg/s. PPT was measured three times over 10 s intervals, and the average value was recorded as the PPT.

Two adjustable straps connected to the load cells were positioned over the acromion of both shoulders (Figure 1). The subject was instructed to keep their trunk against the back of the chair and both the straps were tensioned to avoid any shoulder movements. The subject was then instructed to perform a shoulder elevation task that consisted of pushing up both shoulders towards the ceiling. Two maximal voluntary contractions (MVCs) of shoulder elevation were performed, each lasting ~4 sec with 2 min rest in between. The subjects were asked to reach their maximum force gradually and were verbally motivated by the investigator. For each of the two MVC contractions, the average value around the maximum force was considered and the highest of the two values was taken as the reference MVC. After ~2 min of rest the subject performed a series of 6 ramped contractions from 0-15-0% and 0-60-0% MVC each of 60 sec duration. The order of the ramp contractions was alternated (15%, 60%, 15%, 60%, 15%, 60%). Visual feedback was provided by means of a moving arrow and two moving bars on a screen positioned ~1 m in front of the subject. EMG and force signals were acquired during each contraction.

Electromyography

Surface EMG was detected in a monopolar referenced configuration with a semidisposable adhesive grid of electrodes (model ELSCH064, OT-Bioelettronica, Torino, Italy). The grid consisted of 13 rows and 5 columns of electrodes with one electrode absent at the lower left corner. The diameter of each electrode is 2 mm and the inter-electrode distance 8 mm in both directions.

Firstly, the innervation zone of the upper trapezius was identified using a linear electrode array and the electrode grid was then positioned medial to this point, with the fourth row along the X-axis of the ALS (Figure 2). The rows of the electrode grid were positioned parallel to the line between C7 and the acromion. The grid was fixed to the skin with double adhesive tape following skin preparation by gentle local abrasion with abrasive paste and cleansing with water. The electrode cavities were filled with conductive paste to ensure a proper electrode-skin contact.

The EMG signals were amplified (EMG-USB2 amplifier, OT-Bioelettronica, Torino, Italy), sampled at 2048 Hz and stored on a PC after 16 bit A/D conversion. A reference electrode was placed around the right wrist.

Force

Shoulder elevation force was measured with two load cells that operated linearly in the range 0–1000 N (Mod. TF2/S, CCT Transducers, Torino, Italy). The load cells, fixed on a wooden plate on the ground, were secured over the subject’s shoulders (over the acromion) with two adjustable straps. The force signals were amplified (MISO-II, OT-Bioelettronica, Torino, Italy, bandwidth 0–80 Hz) and stored on a PC (sampling rate 2048 Hz; 12 bit A/D converter). The force signal was presented as visual feedback to the subjects during the shoulder elevation tasks.

Signal processing

For each of the two force levels, the force and EMG signals of the three ramp contractions were visually inspected, and the best of the three (in terms of EMG signal quality and precision of the force with respect to the target) was selected and used for further analysis. Single differential (SD) signals were computed for each pair of adjacent electrodes by differentiating the monopolar signals of the adjacent columns (SD longitudinal along the direction of the muscle fibers). The last row of channels (13th) was excluded from further analysis because of the absent electrode in the lower left corner, in order to have a rectangular grid of 12x4 SD channels. The SD signals were digitally filtered with a 4th order Butterworth noncausal filter (20– 450 Hz) in order to reduce instrumentation noise and slow transients, and divided in epochs of 1 sec. Average rectified values (ARV), were computed for each channel and for each epoch. The ARV computed in each channel were combined to generate a 12x4 topographical map of EMG amplitude (ARV) (Figure 2). The maps of ARV were computed for each epoch and the maximum value was extracted from each row of each map, leading to a vertical vector of 12 elements for each epoch. The values for the 60 epochs were stored in a table of 12x60 elements where the rows represented the positions of the electrode in the Y-axis direction and the columns represented the time instants and displayed as color images (Figure 3). The peaks of the ARV maps were computed for each time instant and traced over the images, in order to describe the location of EMG signal amplitude of the upper trapezius muscle. The distance between EMG peaks and MTrP location was computed in the Y-axis direction in order to describe the distance between MTrP and the most active muscle fibers of the upper trapezius, which are assumed to be parallel to the ALS (Figure 4).

The error of the force with respect to the target force was computed as the mean of the absolute difference between the actual force and the requested force profile (equivalent to the ARV of the error). The error was normalized with respect to the instantaneous target force values and expressed as a percentage (% TF). The analysis was performed separately for 15% and 60% ramps and also for the two portions of the ramps (*(up and down slope*). The force error provides an indication of the accuracy of task performance.

Statistical analysis

A Shapiro-Wilk test for normality was performed ($p <0.05$) on all dependent variables and indicated the need to use non-parametric statistical methods. Mann-Whitney U test was used to test for a differences in the accuracy of force between groups and to test for a difference between groups in EMG amplitude, normalized with respect to the ARV computed during MVC (ARVn), at different force levels (5-10-15 % MVC or 20-40-60 % MVC) Friedman test was used to determine if there were differences in the position of peaks of the EMG signal amplitude during the ramps at different force levels (5-10-15 % MVC or 20-40-60 % MVC) in both subject groups. Mann-Whitney U test was used to test for a difference in the position of peaks of EMG signal amplitude during both ramps between groups.

Descriptive statistics were used to determine the location of the peaks of EMG signal amplitude according to the ALS, and their distances along the Y-axis from the MTrP location during both ramp contractions. In the subjects with pain and MTrP, Spearman correlation analysis was carried out to test whether there was any significant relationship between the location of the peak of EMG signal amplitude and the MTrP location during both ramp contractions.

Statistical analyses were performed with SPSS Version 22.0 (IBM Corp., Armonk, NY, USA). Statistical significance was set to α=.05.

RESULTS

Clinical features of the individuals with myofascial pain and MTrP in right upper trapezius are summarized in Table 1. None of the asymptomatic subjects showed the presence of spot tenderness within their right upper trapezius.

All subjects completed the submaximal shoulder elevation tasks. The groups were similar at modulating shoulder elevation force according to the visual feedback during both ramped contractions, and there was no significant difference in task performance between groups. The force errors are presented in Table 2 and confirm that both groups were able to perform the task with the same degree of accuracy. Moreover no significant differences were observed between the force errors computed in the two portions of the ramps or between the different force levels (15% and 60% MVC).

Values of ARVn obtained during the ramped contractions for both groups are summarized in Figure 5a and 5b. A significant difference between groups was detected at 15% MVC ($p = .046$) and 5% MVC (down slope, $p = .040$). The position of the peak EMG amplitude did not differ across the different force levels of the 15% MVC ramped contractions for either group (Friedman's test: asymptomatic, $p = .644$; pain and MTrP; $p = .140$), whilst it did change significantly across the different force levels of the 60% MVC ramped contraction for both groups (Friedman's test: asymptomatic, $p = .008$; pain and MTrP; $p = .001$). The position of the EMG peak amplitude was significantly different between groups for the ramped contractions at 15% MVC ($p = .010$), 10% MVC (down slope, $p = .016$), 5% MVC (down slope, $p = .007$), 60% MVC ($p = .019$) and 40% MVC (down slope, $p = .026$) (Figure 5c and 5d).

The location of the peak EMG amplitude in the participants with pain and MTrP was -0.32 ± 1.2 cm at 15% MVC and -0.35 ± 0.9 cm at 60% MVC relative to the ALS. In the asymptomatic subjects, the peak EMG amplitude was 1.0 ± 1.3 cm at 15% MVC and 1.3 ± 1.1 cm at 60% MVC relative to the ALS. The distance between the peak EMG amplitude and the location of the MTrP along the Y-axis was 1.51 ± 1.19 cm and 1.34 ± 1.00 cm at 15% and 60% MVC respectively

(Figure 6). No correlation was observed between MTrP and the peak EMG amplitude position during the ramped contractions at either force level (15%: rs = .039, p=.9; 60%: rs = -.087, p=.778).

DISCUSSION

This study evaluated the topographical distribution of upper trapezius muscle activation in people with and without myofascial pain and MTrP in the upper trapezius muscle during a shoulder elevation task. The results showed that the two groups were similar at modulating shoulder elevation force according to the visual feedback during both ramped contractions, and there was no significant difference in task performance between groups. Upper trapezius EMG amplitude was modulated with force intensity and notably the people with myofascial pain and MTrP in the upper trapezius muscle showed higher activity, with this becoming statistically significant at the peak of the 15% MVC ramped contraction and at the end of down slope of the 15% MVC ramp (i.e. 5% MVC). Importantly, a difference in the location of peak upper trapezius muscle activity was also noted between groups both at the peaks of the ramps (15% MVC and 60% MVC) and during the down slope which partially supports our hypothesis. Specifically, the data showed that the peak EMG amplitude was located at a more caudal location in the subjects with myofascial pain and MTrP compared to the asymptomatic controls. The MTrP were located in a well-defined area of the upper trapezius muscle as previously observed [15]. However, novel to this study, we showed that there was no spatial correlation between the location of the MTrP and the position of the peak EMG amplitude. MTrPs are typically defined as a peripheral pain generator that may induce central sensitization. Proposed treatments such as dry needling and ischemic compression are passive and usually active exercise to address motor control are not considered. The present results support previous findings of altered muscle activation in people with myofascial pain during shoulder abduction [28] and provide the basis for future research on the role of active exercise in the treatment of myofascial pain.

The observed change in the peak position during the course of ramped contractions reflects progressive recruitment or derecruitment of motor units and/or modulation of the discharge rate of motor units in different locations within the upper trapezius muscle. Previous work has shown that the upper trapezius muscle shows non-uniform activation and that not all regions within the upper trapezius muscle adapt in the same way to load [22, 29, 30], fatigue or pain [31, 32]. Our results confirm the non-uniform activation of the upper trapezius muscle and, similar to the results Holtermann and Roeleveld which showed that the activation of the upper trapezius muscle is not spatially uniform during intense ramp contraction, the current data also showed variation of the location of the peak EMG amplitude, but only during the 60 % MVC ramped contraction [33]. On the contrary we did not detect a change in peak EMG amplitude location during the low level force ramp to 15% MVC probably due the limited force modulation requested during this task.

The location of peak muscle activity occurred within the upper region of the upper trapezius muscle where the fascicles act as an agonist for shoulder elevation and facilitate stabilization of the scapula [34, 35]. However, the region of peak muscle activity was located at a more caudal location for the subjects with pain MTrP. This observation is in line with previous studies investigating the effects of experimentally induced muscle pain on the spatial distribution of upper trapezius activity [23, 36, 37]. Specifically, it has been shown that acute muscle pain induces a caudal shift of the upper trapezius muscle activity and this occurs regardless of the site of noxious stimulation within the upper trapezius muscle [23]. Thus the current results provide further evidence of a change in the spatial distribution of upper trapezius muscle activity in painful conditions. Considering that the subjects with pain showed higher activity in regions of the muscle which would not normally be as active, this change in the pattern of muscle activation can be considered as an inefficient motor strategy which may even perpetuate the painful condition in the long term.

A main aim of the study was to examine the relationship between the location of the MTrP and the location of the peak EMG amplitude. The data show that, despite the caudal shift of the distribution of upper trapezius muscle activity in the subjects with pain, there was no association between the location of peak muscle activity and the location of MTrP. Thus we could not confirm that the muscle fibers close to the MTrP exhibit a significant increase in surface EMG amplitude, as some previous reports suggest [18]. This is a novel finding which provides new insight into the association between peak muscle activity and the location of MTrP. We suggest that when the upper trapezius muscle is painful, the motor adaptation aims preferentially to minimize activation of the cranial region; possibly because this region has higher pain sensitivity [38].

Limitations

When considering the reported results, it important to remark that we established the location of each MTrP using its spot tenderness and by identifying a discrete point according to the ALS. However, MTrP hyperalgesia, defined using spot tenderness, may not be limited to a discrete point and may extend through the taut band. We did not collect information regarding the presence of additional MTrP in the symptomatic group which may be a limitation of the study.

Our symptomatic group were fairly homogenous for most of the clinical features assessed and only one subject didn't recognize familiar pain upon palpation of the MTrP. More than half of the subjects complained of referred pain during the spot tenderness compression. The MTrP were located in well-defined area of the upper trapezius muscle as already observed in two recent studies that adopted the same ALS [15, 27]. Although we did not distinguish between active and latent MTrP in the current study, all of the symptomatic subjects except for one, respected the criteria for active MTrP [28] and showed low PPT when compared to both active and latent MTrP recently observed in two clinical studies [30, 31].

The sample size was small and was not determined *a priori*. Rather, we recruited subjects based on convenience sampling and sought to recruit a similar size which was sufficient to show differences between painful and non-painful conditions in previous high-density EMG studies [23,24]. Despite being small, the sample size was sufficient in this study to show group differences. Nevertheless, it important to note that the enrolled subjects were highly selective (i.e. relatively young with pressure-sensitive MTrP in the right upper trapezius muscle, as evidenced by their relatively low PPT). Thus extrapolation of these findings to different populations should be done with caution. Moreover, it should also be noted that the subjects included in this study reported acute pain (onset within the previous two weeks) and different observations may be expected in people with long-standing symptoms.

The EMG peak position was established during a shoulder elevation task using a standardized positioning of subjects. But small changes of posture may have occurred during the contractions which may have affected the peak position of upper trapezius muscle activity. However, an investigator carefully monitored the subjects' posture to ensure a consistent starting posture and performance during the task therefore variations in posture are unlikely to explain the differences observed between groups.

The upper trapezius muscle is complex muscle which is activated during many movements and different tasks. In this study we evaluated peak activity of the upper trapezius muscle during shoulder elevation since the upper trapezius acts as an agonist during this task. However, generalization of the results to different movements and tasks should be done with caution. Moreover, we did not measure resting EMG, which, considering the results of earlier studies, may have differed between groups.

CONCLUSION

During an isometric submaximal shoulder elevation task, the location of peak upper trapezius muscle activity was located more caudal in people with myofascial pain and MTrP when compared to asymptomatic individuals indicating a different motor strategy for the task. This change in the topographical distribution of muscle activity may have a role in the clinical course of myofascial pain. However, the location of peak muscle activity was not associated with the specific location of MTrP.

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TABLE LEGENDS

Table 1. Clinical features of the enrolled individuals with myofascial pain and MTrP in right upper trapezius. Third to sixth column indicates the positivity for the MTrP criteria, the 7th column indicates the spot tenderness location according to the ALF, the last column reports the PPT over the spot tenderness.

Table 2. Force errors during the ramp contractions computed for the two portions of each ramp (up and down slope). The error was computed as the mean of the absolute difference between the actual force with respect to the theoretical force profile requested. The error was normalized with respect to the instantaneous target force values and expressed as a percentage (% TF).

FIGURE LEGENDS

Figure 1. Experimental setup, subjects sat in a chair with their trunk against the chair. Two adjustable straps, connected to load cells (Mod. TF2/S, CCT Transducers, Torino, Italy) fixed on a wooden plate, were tensioned over the acromion of both the shoulders. The subject was instructed to perform a shoulder elevation task that consisted in pushing up both shoulders towards the ceiling. An electrode matrix (model ELSCH064, OT-Bioelettronica, Torino, Italy) was placed on the upper trapezius, and a visual feedback was provided means of a moving arrow and two moving bars on a screen.

Figure 2. A) Position of the electrode grid over the right upper trapezius muscle. The electrode grid was positioned on the anatomical reference system (ALS), medially to the innervation zone and with the fourth row along the X-axis. An example of an EMG amplitude map (12x4 elements) of a single epoch (1 sec.) is superimposed over the electrode grid. B) Example of single differential EMG signals detected from each row (1 to 12) of the grid is shown.

Figure 3. Representation of average rectified values (ARV) extracted for the 60 epochs during the ramp contractions at 15 and 60% MVC recorded from representative subjects: two asymptomatic subjects (A,C) and two subjects with pain and MTrP in the right upper trapezius (B,D). Black curves represent the location of the ARV peak along the Y-axis for each time instant.

Figure 4. Examples of topographical maps of the average rectified value (ARV) detected at the time instant corresponding to the maximal force value during ramped contractions at 15% and 60% MVC from representative asymptomatic subjects and subjects with pain and MTrP during ramped contractions at (A) 15% and (B) 60% MVC. The grey circles represent the location of the MTrP according to the ALS.

Figure 5. Mean (± SD) of the (A,B) normalized average rectified values (ARV) and (C,D) ARV peak position recorded from asymptomatic subjects and subjects with pain and MTrP during ramped contractions at 15% and 60% MVC. * = $p<0.05$

Figure 6. Location of the MTrP according to the ALS (grey circles). Blue and red rectangles represent the distribution (mean and SD) of the EMG amplitude peaks computed at the maximum value of both ramped contractions at 15% and 60% MVC in the asymptomatic subjects and subjects with pain and MTrP (blue and red respectively).